AN INTRODUCTION TO MOTOR VEHICLE EMISSIONS INSPECTION AND MAINTENANCE PROGRAMS

Environment CANADA Environnement
2035110A VOL ISS 75 870900
EXC # 001
TD 171.5.C3 R462
<REPORT> IP

OOFF

By: D.L. Cope

Transportation Systems Division
Industrial Programs Branch
Environmental Protection Directorate
Environment Canada

IP-75

September, 1987

REVIEW NOTICE

This manuscript report has not undergone a detailed technical review and the content does not necessarily reflect the views and policies of Environment Canada. Mention of trade names or commercial products does not constitute endorsement for use.

Comments concerning the content of this report should be directed to:

Transportation Systems Division
Industrial Programs Branch
Environment Canada
Ottawa, Ontario
K1A 1C8

SUMMARY

New motor vehicles sold in Canada have emission control systems which limit the quantity of carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NO_x) emitted to levels required by standards via regulations under the authority of the Motor Vehicle Safety Act. However, laboratory tests and checks of vehicles operating on the roads and highways have shown that tampering with emission control systems; misfuelling "unleaded fuel only" vehicles with leaded fuel; and inadequate maintenance can result in vehicles emitting pollutants in excess of the levels specified for new vehicles. In urban areas of Canada where there are chronic air pollution problems due in part to excess emissions from motor vehicles, an inspection and maintenance (I/M) program is a technique which could be used to enforce anti-tampering/anti-misfuelling legislation and to reduce those excess vehicle emissions.

An I/M program usually consists of a regularly scheduled inspection of vehicles in a designated area to detect those vehicles emitting pollutants at rates greater than selected specifications or with inoperative or missing pollution control equipment. The owners of vehicles which fail an inspection are required to have them repaired before the vehicles can be relicenced. A compulsory inspection encourages owners not only to have their vehicles maintained in accord with a manufacturer's schedule but to avoid tampering and misfuelling.

Compulsory inspection and maintenance programs for light duty vehicles have been in operation in certain areas of the USA since 1974. At present there are programs in over 50 urban areas in 31 states. Agencies considering the implementation of I/M in Canadian urban areas have a considerable data base of information to consult when researching possible program types for their area.

However, regardless of final program style, a phased approach to I/M implementation is suggested. The first step in the process would be an extensive publicity campaign to highlight the damage both to the environment and to an owner's expensive vehicle which results from tampering, misfuelling or insufficient maintenance. An education program to include automobile owners, dealers, mechanics and students would follow the publicity campaign along with a series of road-side vehicle spot checks plus an analysis of airshed pollution sources. The latter two activities provide an agency with data for assessing the effectiveness and potential impact of an I/M program and its various components.

RÉSUMÉ

Les nouveaux véhicules automobiles vendus au Canada sont munis de dispositifs antipollution qui réduisent les émissions de CO, HC et NO_x dans la proportion requise par les normes spécifiées dans le règlement d'application de la Loi sur la sécurité des véhicules automobiles. Toutefois, des essais en laboratoire et des essais effectuées sur des automobiles utilisant les voies de communication et les autoroutes ont démontré que l'altération des dispositifs antipollution, l'emploi d'essence contre-indiquée et le manque d'entretien préventif peuvent causer la production excessive d'émissions.

Dans le cas des régions urbaines du Canada où il existe des problèmes chroniques de pollution atmosphérique dus principalement à la trop forte quantité d'émissions produites par les automobiles, il est proposé de mettre en application des programmes de vérification et d'entretien (V/E) afin de réduire ces émissions. Un programme de ce genre consiste à vérifier régulièrement les véhicules en service dans le but de dépister les cas où la quantité de polluants qui se dégagent est supérieure aux normes établies. L'automobiliste pris en défaut doit alors faire réparer son véhicule avant une nouvelle vérification.

Des programmes obligatoires de vérification et d'entretien des véhicules légers sont en vigueur dans certaines régions des États-Unis depuis 1974. Actuellement, il existe des programmes de ce genre dans plus de 50 régions urbaines dans 31 États. Les organismes qui envisagent la mise en application de progammes de V/E dans les villes canadiennes ont accès à une base de données considérable leur permettant de choisir le type de programme qui convient.

Toutefois, la mise en oeuvre d'un programme de V/E devrait être graduelle, quel que soit le type de programme finalement adopté. Avant de commencer à effectuer des vérifications obligatoires, un organisme devrait lancer une vaste campagne publicitaire pour mettre en évidence les dommages qui peuvent être causés à l'environnement et aux automobiles eux-mêmes par l'altération des dispositifs antipollution, l'utilisation d'essence contre-indiquée ou le manque d'entretien. Un programme d'information des vendeurs d'automobiles, des mécaniciens et des étudiants en formation suivrait la campagne de publicité. Une série de vérifications au hasard ou d'enquêtes sur les émissions des véhicules en service ainsi qu'une analyse des sources de pollution atmosphérique devraient faire partie intégrante de la mise en application graduelle du programme et fourniraient à un organisme les données nécessaires pour déterminer l'efficacité et les effets possibles des divers éléments d'un programme de V/E.

ACKNOWLEDGEMENTS

I wish to thank J. Libman, F. Lavallée, R. Solman, T. Dann, E. Wituschek, and D. Poon of Environment Canada along with D. Gourley of Transport Canada for their help and advice. I also wish to thank the personnel of the British Columbia Ministry of the Environment for their assistance.

TABLE OF CONTENTS

		Page
SUMMARY		ii
RÉSUMÉ		iii
ACKNOWLEDGEMENTS		iv
TABLE OF CONTENTS		v
LIST OF TABLES		vii
1	BACKGROUND	1
1.1	The USA	1
1.2	In Canada	3
2	WHAT IS A MOTOR VEHICLE EMISSIONS I/M PROGRAM?	4
2.1	The Phased Approach	4
3	SELECTING THE TYPE OF I/M PROGRAM FOR YOUR AREA	7
3.1	Type of Test Facility	7
3.1.1	Centralized Program	7
3.1.2	Decentralized Program	8
3.1.3	A Hybrid Program	9
3.2	Facility Operation	9
3.2.1	By Government Employees	9
3.2.2	By a Single Contractor	9
3.2.3	By Numerous Small Licenced Garages	10
3.3	Frequency of Inspections	10
3.3.1	Annual Inspection	11
3.3.2	Biennial Inspection	11
3.3.3	Inspection On The Sale or Resale of a Vehicle	12
3.3.4	Spot Checks	12
3.4	Enforcement	13
3.4.1	At Registration	13
3.4.2	Sticker Enforcement Using Local Police Officers	13
3.4.3	Computer Matching	13
3.5	Program Style - Observations and Recommendations	14
3.6	Quality Control - Audit Function	15
4	TEST PROCEDURES AND INSPECTIONS	17
4.1	Idle Emissions Test	17
4.1.1	Preconditioning	19
4.1.2	Cutpoints or Idle Emission Specifications	19

		Page
4.1.3	Exhaust Test Analyzer	20
4.2	Tampering Check	21
4.2.1	Liability and Recommendations	23
5	ADDITIONAL I/M PROGRAM FEATURES	25
5.1	Test Fees and Waivers	25
5.2	Exemptions	28
5.3	Training and Experience	29
5.4	Stringency - Failure Rate	30
6	POTENTIAL EMISSIONS REDUCTIONS	31
6.1	ATP Required for NO_x and Evaporative HC Reductions	33
7	DISCUSSION	35
8	CONCLUSIONS	40
APPENDICES		
A	MOTOR VEHICLE EMISSION STANDARDS PLUS THE FEDERAL TEST PROCEDURE	41
B	RECENT CALIFORNIA I/M DATA	47
C	MOTOR VEHICLE INSPECTION AND MAINTENANCE PROGRAM BIBLIOGRAPHY	53

LIST OF TABLES

Table		Page
1	RECOMMENDED I/M PROGRAM FEATURES FOR MAXIMUM EFFECTIVENESS	5
2	COMPONENTS AND TESTS WHICH SHOULD BE INCLUDED IN A TAMPERING CHECK	22
3	ESTIMATED IMPACT OF I/M ON IN-USE LDV HYDROCARBON EMISSION FACTORS	32
4	ESTIMATED EFFECTIVENESS OF CALIFORNIA'S I/M PROGRAMS	33
5	PROGRAMS OR LEGISLATION IN THE U.S.A. WHICH EASE I/M IMPLEMENTATION AND OPERATION	36
6	EMISSION CONTROL WARRANTIES BY MANUFACTURER IN CANADA	38

1 BACKGROUND

The purpose of a so-called vehicle emissions Inspection and Maintenance, I/M, program is to identify vehicles with excess emissions or inoperative emission control components and to affect repair. In 1985 the results of investigations into excess emissions from in-use light duty vehicles led Environment Canada to suggest that control agencies consider I/M programs for areas where urban air quality problems resulting from excess vehicle emissions are of concern (33)*. This report outlines the principal features of I/M programs and how they could apply in a Canadian context.

I/M programs have been in operation in the United States since 1974 and there is considerable published information describing the implementation, operation and effectiveness of these programs. The list of published reports includes second generation material which analyzes many of the existing I/M programs and highlights their problems and successes. Those wishing to study I/M programs in greater detail are referred to the material listed in the I/M bibliography, Appendix C.

1.1 The USA

In the United States the federal Environmental Protection Agency (EPA) has regulated standards for ambient air quality (in Canada there are non-regulated federal air quality objectives). In many urban areas in the U.S.A. the standards for carbon monoxide (CO) and/or ozone are exceeded on a regular basis, and in a number of these same areas the EPA has judged that "excess" emissions from motor vehicles are a major reason for the elevated ambient pollution levels.

In reference to vehicle emissions, the key word in the last statement is "excess". In order to control vehicle generated pollution, the federal government in the United States (as in Canada) has set maximum emission levels for new motor vehicles**, however, tests on in-use vehicles, that is vehicles operating on the urban roads and highways in the U.S.A., have shown that many vehicles have emissions of CO along with oxides of nitrogen (NO_x) and hydrocarbons (HC), the latter two pollutants are ozone precursors, which are far in excess of the standards for new vehicles.

---

* The numbers in brackets refer to the reports listed in the bibliography, Appendix C.

** The emission standards for new vehicles in the USA have been stricter than Canadian standards since 1975. By the 1988 model year the Canadian and USA, 49 state standards for new light duty motor vehicles will be virtually identical (Appendix A). Note that emissions standards in California are, in some case, lower than the USA, 49 state standards.

These excess emissions should not occur since the emission control equipment originally installed on new vehicles is designed to keep emissions at or below the vehicle emission standards for the useful life of the vehicle, defined in the legislation as 5 years or 50 000 miles. Extensive field surveys (24, 25, 60) involving vehicles from the in-use fleet have shown that tampering with emission control hardware; the misfuelling of "unleaded fuel only" vehicles with leaded fuel; and insufficient maintenance are the principal reasons for the excess emissions. Canadian in-use vehicle tests, although less extensive than those conducted in the USA, show similar results (33).

The impact of tampering with vehicle emissions control components and the frequency of occurrence of such tampering is described in detail in a number of publications. Readers interested in more details on the tampering phenomenon are referred to the reports listed in the bibliography, Appendix C. References 66 and 67 in particular discuss tampering in general and the results of tampering experiments on Canadian vehicles.

In the 1970s, in an attempt to rectify urban air pollution problems, the EPA decided that ambient levels of HC, CO, and NO_x could be reduced by reducing or eliminating excess vehicle emissions and that the inspection and repair of in-use vehicles was a cost-effective way of decreasing those excess emissions (8). In the urban areas where pollution levels exceeded the standards for CO, ozone or both, the EPA ordered state governments to implement inspection programs.

As of September, 1986 there were motor vehicle emissions inspection and maintenance programs operating in 57 urban areas in 31 states (2, 49, 54). The first I/M programs began operation in 1974, but the majority, 36 of 46 programs listed with a start date in reference 2, commenced operation in 1983 or later. (Of the 57 urban areas some are part of the same overall state I/M program. The details of 46 I/M programs with separate start dates are listed in reference 2.)

However, it is important to note that the situation with respect to I/M programs in the USA is not "all roses". Many of the urban areas involved in I/M programs are still listed as non-attainment with respect to the ambient air standards, and the effectiveness of I/M programs in controlling excess emissions, particularly for new technology vehicles, has been questioned (63, 69, 72).

Regardless, the EPA has indicated that in spite of non-attainment in many areas, I/M programs are still an effective technique for emissions reduction. If there are problems they are caused by poor program design and/or inadequate quality control which results in some programs achieving greater emissions reductions than others (49, 50). The

EPA and other agencies have outlined the most desirable or the optimum I/M program features which they feel are required to achieve maximum emissions reductions (see Section 2).*

1.2 In Canada

Although the federal government sets standards for new vehicle emissions via regulations under the authority of the Motor Vehicle Safety Act, the emissions from in-use vehicles are considered the domain of the provincial governments. While it is true that the federal standards for new vehicles are considered to be in effect for the useful life of the vehicle, 5 years or 50 000 miles by definition, the excess emissions of concern result mostly from in-use tampering, misfuelling and/or insufficient maintenance (33). Consequently regulatory initiatives to correct in-use vehicle emissions excesses are generally considered the domain of provincial governments.

At the date of publication of this report three provinces, Ontario, Quebec and Newfoundland, had general motor vehicle anti-tampering legislation, one other, British Columbia, had an anti-tampering provision in its original vehicle act; and several others were investigating the implementation of such legislation.

Newfoundland has recently developed and enacted anti-tampering legislation, while Ontario, to support its anti-tampering laws, has employed a "spot check" style of vehicle emission inspection in the Toronto area for some time. The latter province is also in the throes of implementing an emission component check as part of their existing "change of ownership" safety inspection requirement. Quebec is actively pursuing a mechanic's information and education program (36) plus they are considering a "spot check" style of enforcement program to support their anti-tampering legislation.

While British Columbia is actively investigating I/M programs for possible use in the lower mainland of that province (65), there are, at present, no regularly scheduled inspection and maintenance programs in operation in Canada for light duty vehicles.

---

* The EPA is also considering methanol-fuelled vehicles, refuelling emissions control, changes to their fuel specifications, and to running their vehicle compliance tests using commercial fuel to account for in-use vehicle emissions differences related to fuel quality. The use of MMT in Canada will also effect HC emissions. A discussion of fuel type, distribution, quality and content is beyond the scope of this report.

2 WHAT IS A MOTOR VEHICLE EMISSIONS I/M PROGRAM?

A motor vehicle emissions inspection and maintenance program is a system for enforcing anti-tampering/anti-misfuelling legislation. I/M programs are designed to detect vehicles which would be classed as "excess emitters" and to reduce emissions by returning the emission control systems on those vehicles to an acceptable condition via repair and reinspection. Such programs normally require motor vehicle owners (usually gasoline-fuelled LDVs only)* to submit their vehicles to a regularly scheduled (annual or biennial) inspection for excess idle emissions and/or pollution control component hardware integrity at either a centrally located test facility or at a licenced garage.

The reason for the vagueness in the preceding statement (in the form of numerous and/ors) is that although the U.S. federal environmental agency may require a state to implement an I/M program in a certain area, they do not legislate the details of the programs to be invoked. Consequently every I/M program in operation in that country is different (2). They differ in areas such as: the frequency of inspection (annual or biennial), the location of inspection facilities (centralized or decentralized), the type of inspection (idle emissions test and/or tampering check), etc. Some of the more important options and features of I/M programs are listed and discussed in Sections 3 and 4.

One of the most comprehensive I/M programs in the USA is in operation in Portland, Oregon. In a detailed analysis of I/M program design a group of investigators concluded that of all the systems in operation in 1985, the Portland program was the only one with no serious deficiencies (34). These investigators listed the features they felt were essential for an I/M program to have a potential to be "most" effective, Table 1. The Portland program has all of these features. A properly designed, efficiently run program is essential for maximum emissions reductions.

2.1 The Phased Approach

As defined, an I/M program is a compulsory, regularly scheduled inspection or test of most of the light duty vehicles on the road in an urban area. The success of such a

---

* Although Heavy Duty Vehicles (HDVs) also contribute to ambient air pollution, I/M programs usually address only Light Duty Vehicles (LDVs), automobiles and light trucks of less than 3855.6 Kg (as defined in the 1988 standards). HDV I/M programs are under investigation in the USA (51) and the EPA is encouraging diesel I/M through the impending change in the Total Suspended Particulate Standard to PM10.(9)

TABLE 1 RECOMMENDED I/M PROGRAM FEATURES FOR MAXIMUM EFFECTIVENESS

An effective I/M program should incorporate all of these features, (34).

1. Stringent Emissions Limits: (These are idle emissions cutpoints and not the FTP standards.)

   - if an idle emissions test is incorporated into the inspection procedure then the emissions limits must be strict enough to detect most excess emitters.

2. Computer Controlled Emissions Analyzers:

   - if an idle emissions test is included, it is recommended that a computer controlled analyzer with electronic data recording be used. Certified calibration gases are also required.

3. Visual Inspections and Functional Checks of Emission Control Systems:

   - also referred to as a Tampering Check or an Anti-Tampering Program (ATP).

4. Sufficient Repair Cost Waiver and Repair Requirements:

   - there should either be no repair cost waiver or it should be set high enough to ensure that most of the vehicles which fail the inspection will be adequately repaired. A repair cost waiver does not apply to damage and deficiencies which result from tampering. All tampering damage must be repaired. Repairs must be performed by licenced mechanics using specific procedures.

5. Strict Controls on Exemptions:

   - the program should limit the number of exemptions for vehicle age, fuel type, etc., in order to include most of the in-use vehicle fleet in a particular area.

6. Adequate Inspection Fees:

   - set high enough to cover the cost of performing a thorough inspection and to cover all operating costs.

7. Effective Compliance Mechanism:

   - for program compliance a vehicle must pass the inspection as a prerequisite of vehicle registration renewal.

8. Quality Control - Data Collection, Training, Inspection Requirements, and Audit:

   - the system must have the potential for ensuring that inspections and repairs are properly performed on the required number of vehicles. A comprehensive Quality Control program with a periodic audit by the control agency is essential.

program will not only require public cooperation, but expenditures by individual vehicle owners on test fees and repairs. It is therefore unwise for an environmental agency to introduce such a program too quickly. To alert the public as to the need for an I/M program in their community and to ease the transition to a rigorous inspection requirement, a phased approach is recommended. To introduce compulsory annual inspections some states ran the first year of their program as a voluntary, no charge inspection program.

The following pre-program steps or activities are suggested to phase-in compulsory I/M:

1) an extensive and repeated public relations campaign that concentrates on automobile dealers and private mechanics as well as the general public. Such a program would be similar to the extensive, multi-media, "Automobile Public Awareness Campaign" funded jointly by Environment Canada and the Petroleum Association for Conservation of the Canadian Environment (P.A.C.E.) in 1986 and 1987 (71);
2) add to the enabling legislation a requirement such as: "...no person shall sell a vehicle in the province unless it is equipped with the systems or devices that were installed on the vehicle by the manufacturer to comply with federal emission control requirements or replaced with an equally effective system or device such that the control system or device be in good operating condition...";
3) develop an instruction package and education program for drivers, students and mechanics. Include a mechanics training program in secondary school and community college curriculla (36);
4) conduct a series of random roadside vehicle surveys to assess the condition of the in-use fleet and to demonstrate to the public the requirements of an emissions inspection. Include an analysis of local airshed pollution sources. These two items allow an agency to assess the effectiveness and potential impact of various I/M program components.

If a control agency should eventually decide not to implement a compulsory inspection program then the four steps listed above could still be implemented to support anti-tampering/anti-misfuelling legislation. Alone they would not have the impact on overall fleet emissions that is possible through a well run, compulsory inspection program, but they should help to improve (reduce) overall fleet emissions to some lesser extent.

3 SELECTING THE TYPE OF I/M PROGRAM FOR YOUR AREA

Once an agency has decided to pursue the compulsory inspection route, they must select the style of program best suited to their needs. Of the many parameters involved in periodic inspection program design, the following options apply to the main program features:

I) Type of Test Facilities.

a) Centralized - a few large test centres.
b) Decentralized - numerous licenced garages or service centres.
c) Hybrid - a combination of large test centres in areas of high population density and licenced garages in less populated areas.

II) Facility Operation.

a) By government employees.
b) By a single contractor.
c) By numerous small private operators.

III) Frequency of Inspections.

a) Annual.
b) Biennial.
c) On Sale or Resale of Vehicle.
d) Spot Checks.
e) Combinations of either a or b with c and/or d.

IV) Enforcement.

a) At Registration.
b) Sticker Enforcement By Local Police Officers.
c) Computer Matching

3.1 Type of Test Facility

3.1.1 Centralized Program. Depending upon the in-use vehicle population, one or more large multi-bay test centres would be built in carefully selected locations.

- the ADVANTAGES include:
  - more efficient control over the quality of the inspections;

- better trained personnel because inspections are the only function of the test centre;
- the facility where the inspections are performed is independent of the repair stations, i.e., the inspectors have no vested interest in the revenue from the repairs required to pass a retest;
- eases the audit function and the processing of data;
- there is a potential for lower inspection costs which should be associated with higher volume specialized facilities.

- the DISADVANTAGES are:

  - one or more large costly buildings must be constructed;
  - construction of the facilities will delay the program start date;
  - there is considerable public inconvenience in driving from outlying areas to a central test facility;
  - long waiting lines may occur;
  - private involvement in the inspection process is restricted to a single contractor (although there will be increased work for repair and service facilities regardless of program type).

3.1.2 **Decentralized Program.** An agency would certify a number of private service centres as licenced inspection stations. Normally if repairs are required to pass a retest they are performed at the same service centre as the inspection.

- the ADVANTAGES include:

  - a large number of private entrepreneurs are allowed to participate in the inspection process;
  - the facilities exist, only test equipment (if required) must be purchased;
  - there is less travel inconvenience for the public;
  - the program would be easier and less painful to cancel or phase-out since there is no substantial capital investment in central test facilities;
  - repairs and tests may be done at the same location on the same day which would be convenient for the public.

- the DISADVANTAGES are:

  - if an idle emissions test is included in the program then each garage must purchase an expensive exhaust gas analyzer to ensure accurate data collection.

Evidence indicates that without government certified, computerized analyzers, the emissions reductions achieved from a decentralized program are minimal (Section 6);

- in order to standardize mechanic training a government test and certification program is required;
- since the test mechanic also repairs the vehicle, a mechanic may claim that expensive but unnecessary repairs are required or, conversely, a mechanic may be tempted to cheat on the test results to please good customers;
- data collection and quality control over a large number of test centres requires an extensive government audit and administration program.

3.1.3 A Hybrid Program. If air quality problems encompass an area comprised of high and low population density, in order to ease the travel inconvenience for those in the more remote locations, an I/M program may incorporate both centralized and decentralized test stations for the high and low density areas respectfully.

A hybrid system would mix the advantages and disadvantages of both styles of test program.

3.2 Facility Operation

3.2.1 By Government Employees. Agency employees would administer the I/M program plus operate a number of centralized test facilities.

- the ADVANTAGES include:
  - private entrepreneurs do not suffer if the program is cancelled;
  - an agency has direct control of all costs and fees;
  - the blame is obvious if the program fails;
  - training can be more easily standardized;
  - there is no conflict of interest with respect to repairs.
- the DISADVANTAGES are:
  - the government is performing a routine service which could be done by industry;
  - a government run program is more subject to short-term program fluctuations to satisfy changing political priorities.

3.2.2 By a Single Contractor. The agency signs a long-term (4 to 5 years) contract for a private company to run a number of centralized test facilities.

- the ADVANTAGES include:
  - the control agency's day to day involvement is reduced to quality control, audit, contract management plus data analysis;
  - the quality of inspections, testing, training, and data can be set via provisions of the contact;
  - there should be no bias with respect to repair recommendations.
- the DISADVANTAGES are:
  - renegotiation of the contract can be difficult since one company now possesses almost irreplaceable expertise;
  - private sector involvement is limited to a single company;
  - if the single company does a poor job the entire future of I/M programs in the area is jeopardized.

3.2.3 By Numerous Small Licenced Garages. A decentralized program where inspections are conducted in private service centres which are owned and operated by non-government, licenced entrepreneurs.

- the ADVANTAGES include:
  - numerous motor vehicle service centres are already available for licencing;
  - the failure or poor performance of a single operator does not jeopardize the program;
  - the public may prefer a local test facility in their neighbourhood run by people they know.
- the DISADVANTAGES are:
  - the quality of the inspection can vary greatly from one garage to the next, therefore a comprehensive quality control program is essential;
  - an agency's data collection function is more difficult;
  - an agency must initiate and maintain operator training and certification programs.

3.3 Frequency of Inspections

An agency must decide how frequently the public must bring their motor vehicles in for an inspection. The size of the test facilities, the cost to administer, and the inconvenience to the motoring public are factors in this decision. For greater fleet

coverage an agency may wish to combine either an annual or biennal inspection with a requirement for inspection on resale and/or periodic spot checks.

3.3.1 Annual Inspection. This is by far the preferred option for the I/M programs in the U.S.A. (2). Only 3 programs list biennial inspection requirements.

- the ADVANTAGES include:
  - since most licencing bureaus require a yearly renewal of vehicle permits, the administration requirements for an annual inspection should easily mesh with the existing system;
  - the public can easily identify with a requirement to have an annual inspection at the same time they renew their vehicle permit;
  - the excess emissions from certain vehicles may significantly increase if the time between inspections is longer than one year.
- the DISADVANTAGES are:
  - a requirement to check emissions certificates adds to the workload of licence bureau staff;
  - the entire LDV fleet must be processed every year.

3.3.2 Biennial Inspection.

- the ADVANTAGES include:
  - recent EPA analyses (50) show that for certain cases, a biennial program may be more cost-effective than an annual program;
  - the annual administrative costs are less because of the smaller volume of vehicles to be processed.
- the DISADVANTAGES are:
  - if administration is geared for yearly vehicle permit renewal, a biennial program could cause confusion both for agency personnel and the public;
  - if centralized facilities are sized for a biennial system, once built it would be difficult to switch to an annual program;
  - a vehicle's emissions can seriously degrade in the two year gap between inspections.

3.3.3 Inspection On The Sale or Resale of a Vehicle.

- the ADVANTAGES include:
  - if it is the only inspection requirement, only a small volume of vehicles per year require inspection, therefore there is less public inconvenience;
  - resale is more common for older vehicles, therefore, since emissions usually increase with vehicle age, many vehicles with very high emissions will be detected and repaired (or scrapped).
  - because it will jeopardize resale value, individuals will be less likely to misfuel or otherwise tamper with vehicles.
- the DISADVANTAGES are:
  - if this is the only inspection requirement, each year the large majority of in-use vehicles will not be inspected and therefore the impact on overall airshed emissions may be negligible;
  - for public convenience it may be necessary to certify and audit a large number of private test centres, therefore an agency's administration costs may remain high;
  - for a decentralized program, because of the few vehicles tested at each station, the test fees in order to cover analyzer costs will be high and the inspectors will be less proficient.

3.3.4 Spot Checks. A spot check for vehicle emissions normally requires a law enforcement officer to flag down motorists at random. A police officer working alone would normally be limited to a simple check for the presence of a catalyst and the fuel inlet restrictor plus a check for visible smoke emissions. An exhaust emissions test and a more extensive tampering check would require control agency personnel to assist the officer. If deficiencies are found, the motorist may be issued a warning requiring repair within a set time limit.

- the ADVANTAGES include:
  - no expensive test facility is required;
  - rapid implementation is possible.
- the DISADVANTAGES are:
  - possible adverse public reaction to being interrupted during a trip;
  - if it is the only inspection requirement, a considerable number of spot checks would be required to achieve significant emission reductions;

- the complexity of the tampering inspection is severly limited if police officers are employed unassisted. Agency personnel may be required in the field to perform the inspection;
- the law enforcement officers will require training and the vehicle inspections will detract from their primary duties.

3.4 Enforcement

3.4.1 At Registration. Documents which certify that a vehicle has passed an inspection or has been granted a waiver are required before a vehicle registration permit can be renewed.

- the ADVANTAGES include:
  - easily incorporated into the existing vehicle permit system;
  - special law enforcement is not required, i.e., if a licence plate is valid then the vehicle has been inspected;
  - consolidates vehicle related items for the public.
- the DISADVANTAGES are:
  - a licencing bureau may feel they cannot support the additional work load;
  - possible difficulties in data handling and administration if more than one government agency is involved in vehicle permit renewal.

3.4.2 Sticker Enforcement Using Local Police Officers. A vehicle attached emissions sticker is issued separate from any motor vehicle permit renewal identification. Less than one-half of tthe I/M programs in the USA employ sticker enforcement and many police departments have complained that a sticker system is difficult to enforce because of staff overload.

- the ADVANTAGES include:
  - government agencies remain separate with respect to administration;
  - no burden on existing vehicle permit system.
- the DISADVANTAGES are:
  - places an additional burden on police departments;
  - the public may be required to visit two different government offices at different times on vehicle related matters.

3.4.3 Computer Matching. When a vehicle passes an inspection at a certified garage, the results are submitted to and entered onto the enforcement agency's computer

data base. At periodic intervals the agency performs a computer match of the required test dates for specific vehicles to the test pass notifications which it has received from the test centres.

- the ADVANTAGES include:
  - the control agency can run the enforcement program without involving the police or the vehicle licencing agency;
- the DISADVANTAGES are:
  - a large capacity, dedicated computer system to rapidly process data is essential;
  - delays in acknowledging the successful completion of an inspection can lead to false failure notifications.

3.5 Program Style - Observations and Recommendations

With respect to the features noted above, an examination of the information on the programs operating in the United States leads to the following observations and recommendations:

a) Centralized/Decentralized/Hybrid Test Facilities

Because of the ease of training, audit, and administration, most control agencies prefer centralized test facilities, but since decentralized programs involve a greater number of private businesses, politicians frequently prefer the latter (34). For large areas a hydrid program may be best suited.

Of the programs listed in reference 2 there are:

- 15 centralized;
- 30 decentralized;
- 1 hybrid.

After the extensive analysis presented in reference 34, the consultants and the state environmental agency recommended a centralized program, however the local politicians voted for a decentralized program. A similar situation occurred in the state of California (34).

b) Government/Contractor/Private Business Operation

The trend in recent years has been toward decreasing government involvement in routine operations which could be run by private companies. The preference for most I/M operations in the USA is private operation; of the 46 I/M programs listed in reference 2, only 4 are run by state or local government personnel.

c) Frequency of Inspections

An annual test for emissions and emissions control component hardware should ensure a greater reduction in excess vehicle emissions. If vehicle permit renewal is annual, a biennial I/M requirement may lead to considerable confusion both for the public and for the vehicle permit administrators.

However, the latest U.S. EPA data show that there may be a cost saving in a biennial program which only requires inspection of one-half of the in-use fleet in an area each year. It is important to note that a biennial program is only estimated to cost less than an annual program when such a program is initiated on a biennial basis; the same cost savings are not seen if an annual program is switched to a biennial program (50). A recent report on the California Smog Check (I/M) Program estimated, under ideal conditions, a decrease in fleet emissions of 2.5% per pollutant if they converted from a biennial to an annual program. (70)

An inspection for emissions control system integrity as part of a province's process for change of vehicle ownership is a method of reducing emissions from older vehicles and could be included in an I/M schedule.

d) Enforcement

Registration-Enforcement is recommended. Many programs have experienced difficulties with police sticker-enforcement. A requirement for an inspection prior to renewal of a vehicle permit appears the most successful approach and the easiest to coordinate with most existing permit renewal systems.

3.6 Quality Control - Audit Function

Regardless of the type and design of I/M program, a tightly administered quality control - audit function on the part of the control agency is required. Quality control not only covers data, it must also cover aspects such as:

- training and certification of mechanics;

- inspection centre certification and licencing;
- specifications for the computerized test analyzer system;
- calibration gas certification;
- quality of inspections and repairs - a referee facility is required for decentralized programs;
- experienced agency experts for troubleshooting and public liaison; and
- the overall efficiency of the enforcement program.

The quality control - audit function is especially critical in decentralized programs where the test centres are not directly controlled by the agency.

In the U.S.A. both the EPA (17, 40, 49) and state agencies (27, 53, 62, 63, 70) perform regular and periodic audits of I/M programs via inspectors, vehicle recalls and covert test vehicles. For example in Colorado where they have a decentralized I/M program "... the Departments of Health and Revenue conduct covert inspections on each of the 1400 licensed inspection stations annually...". In the Colorado program they employ covert vehicles which are preset to fail one or more aspects of the emissions inspection (53). A similar technique is employed in Anchorage, Alaska (62). In California they select private vehicles which fail I/M inspections and use them to test other inspection centres (70).

The need for quality control and audit was emphasized by the results of the EPA's check of late-model year vehicles which failed the Maryland I/M program inspection in the spring of 1986. Extrapolating the results of their study of 178 vehicles, the investigators estimated that "...over 30 percent of the cars that initially failed the Maryland I/M test could have passed a retest...without any repairs being performed..." (63).

It is important for a control agency to recognize that quality control is essential and allocate sufficient funds for a comprehensive program.

4 TEST PROCEDURES AND INSPECTIONS

Most of the I/M programs in the U.S.A. incorporate both an exhaust idle emissions test and an inspection of vehicle emission control components for signs of tampering. An Anti-Tampering Program (ATP) comprised of a visual inspection plus function tests of certain components is vital for I/M program success. Although the idle emissions test was originally thought to be an effective method for detecting vehicles with excess emissions, recent experience, particularly with new technology vehicles (post 1981 model U.S. specification), has led to questions with respect to its validity (70). I/M planners should study the pros and cons of the idle test before deciding to include it in their program.

4.1 Idle Emissions Test

The federal government has emission standards for new light duty motor vehicles and has introduced stricter standards for the 1988 model year (Appendix A). If there is no component damage or breakdown, a vehicle's systems are designed so that its emissions meet the regulated standards for the vehicle's useful life, defined as at least 5 years or 50 000 miles. In Canada to check whether a new vehicle complies with the standard for either CO, NO_x or HC, a deterioration factor is applied to emission test results taken at 4000 miles (to allow for in-use aging) and the resulting product must be less than the new vehicle standards.

However, the check for compliance with the new vehicle standards requires that emissions be measured using a standard reference method known as the Federal Test Procedure (FTP). The FTP employs a Constant Volume Sampling (CVS) system, a chassis dynamometer and the vehicle is operated over a standard driving cycle, (Appendix A).

Because of the equipment needed and the time involved per test, FTP testing is impractical for regular, large volume testing of in-use vehicles as is required in an I/M program. In its place the method of sampling and measuring emissions employed in most of the I/M programs in the USA is the exhaust idle emissions test. A probe which is connected to a gas analyzer is inserted in a vehicle's exhaust pipe and the CO and HC concentrations in the exhaust gases are measured while the vehicle's engine is running at low idle speed (and in certain programs at high idle, 2500 rpm). The measurements are compared to selected idle emission specifications or cutpoints (see Section 4.1.2).

Since there are little or no NO_x emissions from a gasoline-fuelled vehicle at idle, NO_x emissions are not measured in an idle test.

Unfortunately, the idle test is not a standard reference method and there has always been a controversy with respect to the validity of idle test results. Repeated testing by various agencies has confirmed that there is a lack of direct correlation between mass emissions measured using the FTP and the exhaust emissions concentrations measured in an idle test. It is possible that a vehicle which fails an idle test (i.e., has emissions of HC and/or CO greater than an idle cutpoint) will pass an FTP test. This incorrect grading of an in-use vehicle's emissions is referred to as an Error of Commission. The reverse also occurs, passing a vehicle which would fail FTP, and is labelled an Error of Omission.

Questions with respect to the validity of idle test results have come more frequently in connection with new technology vehicles. Recently the California Air Resources Board (CARB) announced that they have encountered problems related to emissions testing of some of the latest technology vehicles in their biennial I/M program. "Some vehicles, as designed, are basically not compatible with the program and have false emission failures or are untestable" (68). "It is almost universally recognized that emissions during typical driving conditions (particularly cold engine start, warmup and acceleration under load) cannot be predicted based on the simple emission testing procedures used in I/M programs... the short test (idle test)... can only identify a gross emitter..." (70).

At least one of the major vehicle manufacturers in the U.S.A. has criticized idle emissions tests especially in connection with newer vehicles employing fuel injection and electronic engine control. This manufacturer felt that idle tests result in too many errors of commission (63, 69). An alternative suggested by this manufacturer was to combine an anti-tampering program with an interrogation of on-board computer diagnostics. Unfortunately, the latter technique would be difficult to implement at present because of the variety of incompatible computer hardware/software employed by the different manufacturers. For a detailed discussion of the idle test and standards see reference 20.

Therefore, for maximum program effectiveness and to reduce errors of both commission and omission, an idle test should be accompanied by a thorough tampering check. Three I/M programs in the USA do not use an idle emissions test (54). The program in Harris County, Texas combines an extensive anti-tampering check with a road test (44). (A few I/M programs employ only an opacity test for visible particulate emissions. Although visible emissions must be checked, they should not be the sole pass/fail criteria.)

Agencies considering the introduction of I/M should familiarize themselves with the controversy surrounding the idle emissions test and design their program to reduce possible errors to a minimum (20, 34, 63, 69, 70). Although there are alternative tests, none are standard methods (54).

4.1.1 Preconditioning. Part of the idle emissions test controversy concerns preconditioning. An idle emissions test must be performed on a fully prepared engine. The EPA has cited insufficient or incorrect preconditioning (allowing sufficient time for an engine to reach operating temperature under road conditions prior to test) as a possible reason for major discrepancies occurring in the test results of vehicles they reexamined during an I/M audit in Maryland (63).

It would seem unwise to employ an idle test unless adequate preconditioning is included in the test specifications. One method of ensuring preconditioning would be to program a test analyzer to only accept input data as correct if and only if a mechanic has indicated that the appropriate preconditioning has been performed. Preconditioning techniques include: running a vehicle at high idle, approximately 2500 rpm, for a short period; taking the vehicle for a road test immediately prior to exhaust gas analysis; or using a chassis dynamometer to allow loaded preconditioning. The latter technique is employed in the Arizona I/M program; although it allows excellent preconditioning, it significantly increases the cost of equipping an inspection station (69). The incremental cost of including a steady state, loaded mode, dynamometer test capability has been estimated at $12,000 to $16,000 (U.S. $) per station (70).

4.1.2 Cutpoints or Idle Emission Specifications

New vehicle emissions are measured in mass units (gm/mi) following the Federal Test Procedure with test results compared to a set of mass emissions standards (Appendix A). However, as previously discussed, because there is a lack of correlation between the idle emissions test results and the FTP results, neither the Canadian nor the U.S. authorities have set idle emission test standards for in-use vehicles (although there is an idle CO certification specification for new cars). Both have, however, recommended cutpoints or specifications for grading CO and HC idle emissions test results. The U.S. EPA recommends 1.2% CO and 220 ppm HC as the levels for all 1981+ vehicles (this model year applies only to U.S.A. specification vehicles) (34). Environment Canada has suggested levels of 1.5% CO and 300 ppm HC (for 6 and 8 cylinder vehicles) for the newest model year tested with a deterioration factor per model year (33). These higher

levels are felt necessary to account for differences in 3-way catalyst technology penetration into the Canadian in-use fleet plus differences in allowable fuel additives.

For initiating an I/M program in a Canadian urban area the recommended cutpoints, listed in reference 33, should be used as a guide. All in-use light duty vehicles which are in proper operating condition, with their original emission control components installed, and set to the manufacturer's specifications should pass both on CO and HC, i.e., have idle emissions less than the values listed.

However, since the composition of the in-use fleet of vehicles can vary considerably from region to region, a universal set of idle test cutpoints may not be appropriate. For example although the U.S. EPA has recommended idle emissions cutpoints, none of the 31 states with I/M programs use exactly the same set of specifications for CO and HC for all model years (2). Any agency considering I/M should perform an extensive emissions survey of their in-use vehicle fleet to ascertain which cutpoints (or pass/fail levels) for CO and HC emissions will produce the stringency level (failure rate) that is most compatible with the desired emissions reductions and public acceptability (see Section 5.4). For detailed discussions of I/M specifications and cutpoints see references 20, 54, 69 and 70.

4.1.3 Exhaust Test Analyzer

It is not only important to select a representative set of emission cutpoints, but to process the test data accurately, fairly and efficiently. A computer controlled analyzer with a built-in data recording system is recommended for the efficient collation of data and accurate comparison to the pass/fail cutpoints. A computer controlled analyzer is specially important for a decentralized program.

An audit analysis of the I/M program in Colorado found that pass/fail decisions made by mechanics were often incorrect because the inspector used either the wrong set of cutpoints for the vehicle model year or knowingly passed a failed car to keep a customer happy (53). The Test Analyzer System (TAS) employed in Anchorage, Alaska circumvents this problem by having the TAS computer set the pass/fail cutpoints in response to the vehicle model year, etc. input by the mechanic. The TAS computer, not the inspecting mechanic, decides whether the vehicle has passed or failed based upon its emissions measurements (62).

A two gas analyzer is normally required to perform an idle test for CO and HC emissions. The cost of these analyzers varies considerably with their quality and complexity. The BAR 84 (Bureau of Automotive Repair, California) analyzer, preferred

by many control agencies in the USA, has the pass/fail cutpoints incorporated into the instrument electronics package.

With computer controlled analyzers the requirement for the operator to interpret emissions data is eliminated. These analyzers can also record vehicle identification parameters along with the results of all visual and function checks on magnetic tape. Analyzer tapes can be collected by a control agency at a later date which greatly reduces data reduction time and eases program audit. This style of data collection is employed in the Anchorage, Alaska I/M program (62).

One concession granted in California when a centralized program was rejected by the legislators was that all analyzers in the decentralized test centres had to be computer controlled and equipped with tape recorders (34). Computer controlled analyzers will also greatly ease the data reduction tasks of the control agencies running centralized I/M programs.

The emission control component identification problems noted in section 4.2 will require that specialized software be developed if computer controlled analyzers are to be used for similar purposes in Canada.

4.2 Tampering Check. A tampering check (also referred to as an Anti-Tampering Program, ATP) includes: a visual inspection of emission control hardware and associated components to see that they are still fitted on the vehicle (as per the manufacturer's original description); a check that all required hoses and wires are still connected and in good condition; plus, where possible, a function test to determine whether certain components are operating.

The most common and simplest form of tampering check is to inspect the fuel inlet to check whether the restrictor (on "unleaded gasoline only" vehicles) is still in place and has not been enlarged. A dummy leaded-gasoline size nozzle should be used to check the restrictor; if the leaded fuel size nozzle can be inserted into the vehicle's fuel inlet then that vehicle fails the inspection. Table 2 lists the components which should be included in an I/M tampering inspection; many programs already include all of these items in their check (2).

In a function test, techniques are employed to discover whether certain components are operating. In California they feel that properly conducted function checks are necessary if maximum emission reduction potential is to be achieved (70). A word of caution however, if a function test is performed it could lead to liability problems if a vehicle is damaged during the test (Section 4.2.1).

Since NO_x emissions are not and cannot, normally be measured in an idle emissions test, a check for the presence and condition, if fitted, of NO_x control components and related accessories is one of the only ways, during a brief I/M inspection, to identify vehicles which may have excess NO_x emissions. The NO_x control components (or components which may influence NO_x control) which should be checked include the catalytic converter (a 3-way catalyst has the greatest impact on NO_x emissions), the EGR valve, plus a computer and related items such as an oxygen sensor.

The federal government also sets emission standards for evaporative HC emissions however, as for NO_x emissions, there is no practicable field or non-laboratory method for measuring evaporative losses. Since evaporative emissions can represent up to 20% of a vehicle's total emissions of hydrocarbons, it is important that an inspection include a check of the evaporative emissions control equipment. The hardware components involved are the evaporation emissions cannister and hoses plus the inspection should include a check that the fuel inlet cap is present and that its seal or seat is still in place.

TABLE 2 COMPONENTS AND TESTS WHICH SHOULD BE INCLUDED IN A TAMPERING CHECK

1)	PCV (Positive Crankcase Ventilation) Valve and Hoses
2)	Air Injection Components (may include a pump and belt)
3)	Spark System (vacuum hose routing and control equipment)
4)	Evaporative Emission Control System - (Cannister and fuel cap)
5)	Catalyst
6)	Fuel Inlet Restrictor and Tank Label
7)	Air Intake (stove pipe, cover integrity and thermostatic control)
8)	EGR (Exhaust Gas Recirculation System) Valve and Sensor
9)	Computer Module (computer, sensors, diagnostic lights and engine warning light)
10)	Fuel Injection/Carburetor System
11)	Oxygen Sensor
12)	Lead Test at the Tailpipe (Plumbtesmo)

A tailpipe lead test may also be included in a tampering check. Lead sensitive paper (trade name Plumbtesmo) is used to check the residue in the tailpipe for the presence of lead in the exhaust of "unleaded fuel only" vehicles. The I/M program in Harris County, Texas is one program which does not employ an idle emissions test, but instead incorporates a very extensive tampering check and relies heavily on the use of the Plumbtesmo lead test (44). Ten of the 46 I/M programs listed in reference 2 employ the Plumbtesmo lead test, and a U.S. EPA evaluation report revealed that plumbtesmo could successfully detect lead in the exhaust of vehicles fuelled with new, low lead-level fuels (73).

Please note one serious problem associated with the implementation of Anti-Tampering Programs in Canada. In the U.S.A. all manufacturers must submit to the federal government lists of the emission control components fitted on each new engine family they certify. There is no such program or requirement in Canada and it would require a restructuring of the entire Canadian new vehicle, self-certification program in order to impose such a legal requirement in this country. A change in this system in the near future is unlikely and therefore agencies will encounter difficulty with original equipment identification.

A requirement for manufacturers to list all emission control components on their Vehicle Emission Control Information label on new vehicles is under investigation by Transport Canada, but it is also unlikely that such a program would come into effect in the near future. Even if it did, it would not be retroactive for older model vehicles. Agencies must investigate alternate techniques to overcome this difficulty. Environment Canada and Transport Canada are now compiling a list of equipment on vehicles for model years 1980 to 1987.

With the advent of the revised Canadian emission standards for new vehicles the emission control component lists assembled in the USA for the 1988 model year and on will be applicable in Canada except for a very small number of vehicles.

4.2.1 Liability and Recommendations. Some agencies in the USA have chosen a virtual "hands off" approach with respect to the vehicles checked in their I/M program. The only contact with a vehicle during the idle emissions test procedure is to insert an exhaust analyzer probe into the tailpipe. The reason for adopting a "hands off" policy is to avoid possible litigation with respect to vehicle or component damage resulting from an underhood inspection.

However, since vehicles that have undergone some form of emission component tampering may pass a test which does not include a thorough check for component integrity, implementing an I/M program which does not include a tampering inspection could result in significant errors of omission. Also, as noted in Section 4.2, evaporative and NO_x control component tampering are unlikely to be detected via an idle emissions test.

Therefore, although an agency must assess the liability aspect of vehicle inspections, a comprehensive tampering check incorporating the items listed in Table 2 is recommended as a vital part of any I/M program.

5 ADDITIONAL I/M PROGRAM FEATURES

When implementing an inspection and maintenance program, in addition to the main program design features discussed in Section 3, an agency must consider a number of other important details and decide which options are best suited to their area and to their in-use fleet. Again the reader is directed to the references in Appendix C for additional discussion of these items (34, 44, 53, 62, 65, 70).

5.1 Test Fees and Waivers

A ticklish point with any program which requires compulsory public participation is the direct cost to the public. An agency may wish to judge a program's desireability on its cost-effectiveness (in dollars per ton of pollutant controlled), but the public's acceptance or rejection of a program will probably hinge on its immediate or "up front" costs. The test fee charged to each vehicle owner is the first direct program cost to the public.

In the USA test fees vary from none in 5 centralized programs to a high of $30 (U.S.) per test in one state. The latter is an exception; most programs charge between $5 and $10 (U.S.). Some programs also charge a retest fee if a vehicle fails and returns after undergoing repair.

It has been claimed that a centralized program can be setup and run at no cost to a control agency because all costs can be recovered from the test fee charged. The Portland I/M program charges $7 (U.S.) which "... pays for the program operation ..." (52). Assuming this is true, then this "cost recovery via test fee" factor should apply to any style program, whether centralized or decentralized, the question is, how large a fee is acceptable and/or practical? An analysis of the test fleet size and composition in a particular area would be required before test fees could be accurately estimated. If the U.S.A. test fees are taken as an example, an I/M program in Canada would most likely have a test fee of $10 to $15 ($ Canada, 1987).

Repair Cost Waiver or repair cap is another important factor that will influence public acceptance and the success of an I/M program. If a vehicle fails an emissions inspection an owner is normally required to have the vehicle repaired within some time limit and returned for a retest. If an I/M program is linked to vehicle permit renewal it is difficult for an owner to ignore or escape the repair/retest requirement other than by selling the vehicle or leaving the I/M area.

However, to ease the burden imposed on the owners of vehicles which fail a test (normally around 30%) many I/M programs have set a waiver, limit or cap to the repair costs. If at retest an owner produces an emissions component repair bill greater than the repair cost waiver, they receive an exemption and their vehicle is relicenced even if it fails the retest. Thirty of the 46 programs listed in reference 2 have repair costs waivers which vary from $15 to $300 (U.S.). In California they employ "Referee Facilities" to check vehicles where the owner has applied for a Repair Cost Waiver (70).

The important exception is that for almost every program the Repair Cost Waiver does NOT apply if the emission control system damage resulted from tampering. For example, if misfuelling had destroyed a vehicle's catalyst or the catalyst had been removed, the owner is required to replace the catalyst even if the cost of the replacement is greater than the Repair Cost Waiver.

The need for a Repair Cost Waivers is not universally accepted in the U.S.A. and their use has caused difficulties for many I/M program administrators. If there is either no waiver or if it is set too high then unscrupulous mechanics may overcharge the public since they know that repairs must be performed for the vehicle to be relicenced. On the other hand, if a waiver fee is too low then a mechanic's fee can quickly exceed the waiver limit and the repairs required to reduce a vehicle's excess emissions may not be performed. The correct setting of waiver fees is considered essential for an effective I/M program (Table 1) (34).

The I/M program in Oregon, which has been referred to as one of the best (34), has no waiver based upon repair expense; all repairs required to reduce emissions to the specified cutpoints must be performed for a vehicle to receive registration renewal. A March, 1986 survey of 1,100 vehicles in that program revealed an overall average cost of repair after failing an I/M test of $50.68 (U.S.). The standard deviation of this repair cost data was $50 to $60 (52).

The Maryland study performed for the U.S. EPA which concentrated on newer technology vehicles, U.S.A. specification 1981 to 1984 models, included a detailed cost analysis. The analysis compared CO and HC emissions reductions to the repair costs to achieve those reductions and one conclusion was that "...over one-half the HC and CO reductions were obtained from the cars which were repaired for not more than $90 (U.S.)...". However, the replacement of major, new technology components can quickly elevate repair costs. The cars "...which received a new catalyst or a new ECM (electronic control module) all had repair costs ranging from $275 to $900 (U.S.) (63). A California study of their I/M program concluded that their $50 repair cost ceiling contributes to incomplete repairs (70).

Because of less strict vehicle emission standards, there has been less penetration into the Canadian in-use fleet of 3-way catalyst technology. However, the percentage of new technology vehicles is increasing in this country and the following statement is important with respect to the impact of that technology on I/M programs. "Electronics and improved quality control (for vehicles) may have benefitted the consumers; however, when a failure occurs, which is rarer than in the past, the cost of repair is often higher" (52). In California their I/M program analysis revealed that it would require a repair cost ceiling of $400-$500 to repair all 1980 and newer (U.S. specification) vehicles. Approximately 16% of the vehicles in this category would not be repaired with a ceiling less than $400. Currently, about 25% of all failed vehicles in the California program receive waivers (70).

The U.S. EPA is considering imposing a requirement for higher Repair Cost Waivers on many of the existing I/M programs as a method of achieving greater emissions reductions from those programs.

The following must also be considered when considering a Repair Cost Waiver:

- lower income families frequently operate older, higher mileage vehicles. A high repair cost ceiling may eliminate such a family's chances of owning and operating a vehicle;
- a carburetor is normally considered an emission control component and a mechanic's non-emission related repairs to this component may push fees to greater than the waiver cost with little emission reduction achieved;
- aftermarket components, those components produced by companies other than the Original Equipment Manufacturer (OEM), are often less expensive, however, they may also be less effective in reducing emissions. This is particularly true with respect to aftermarket catalysts which may sell for 1/3 the price of the original. The U.S. EPA has recently developed a policy with respect to the use of aftermarket catalysts (58). An agency implementing I/M will have to adopt some such policy in order to deal with this potential problem.

Considering the arguments presented in the preceding discussion it is difficult to recommend a specific repair waiver fee, if any, but if a decision is made to employ a waiver, the dollar value should be set high enough to ensure that the most frequently defective emission control components are identified and repaired. Regardless, one of the main aims of an I/M program is to discourage tampering and misfuelling, therefore an agency must require, without exception, all repairs to correct defects which result from tampering.

5.2 Exemptions

The intent of an I/M program is to inspect the majority of the in-use light duty vehicles in a particular area. However, in order to simplify testing procedures plus reduce both administration requirements and costs, an agency may choose to exempt certain vehicles, especially when, because of their numbers and miles travelled, the total emissions from those vehicles are only a minor contributor to airshed emissions. For example, only 2 of the 46 programs listed in reference 2 include motorcycles and diesel-fuelled light duty vehicles in their testing. Both motorcycles and diesels require a different type of testing plus special training for inspectors. Only one I/M program lists exemptions as "none".

Other exemptions include: (2)

- Other-fuel vehicles (propane, natural gas, neat alcohol, electric)	17	programs
- Air cooled vehicles (reason not specified)	1	program
- Heavier vehicles (upper weight for testing varies, 5000 to 18 000 lbs)	35	programs
- Older vehicles (from test none older than 1961 to none older than 1980)	41	programs

For "other-fuel vehicles" an agency should inventory the number of each type within the I/M program area to determine if they warrant the complication of requiring their emission inspection. Vehicles fuelled with low level alcohol blends (normally 10% or less alcohol in gasoline) are considered gasoline-fuelled and therefore they are included in an I/M program.

Most I/M programs do not require Heavy Duty Vehicles (usually defined as having a GVWR of greater than 3856 Kg, 8500 lbs) to be inspected (although the upper weight limit for inspection varies from state to state) but they do include light duty gasoline-fuelled trucks.

There should be little difference between a light duty gasoline-fuelled truck inspection and an automobile inspection. Emissions from new light duty trucks are regulated in a similar manner to automobiles, therefore the emission control equipment is also similar for both types of vehicle. It is estimated that the benefits of including light duty trucks may be equal to, or greater than, the emissions benefits for automobiles (50). It is therefore recommended that light duty gasoline-fuelled trucks be included in an I/M program.

Heavy Duty Vehicles can present problems since specialized training and equipment would be required and specially sized facilities would have to be built. The California Air Resources Board (ARB) has commissioned a study to develop I/M procedures for heavy duty diesel trucks and buses and to estimate the benefits and costs of implementing a heavy duty diesel I/M program. A full report on that project should be available late in the fall of 1987 (51).

The definition of "older" vehicle varies with the program, but most programs exempt 1968 and older model years. Considering the number of vehicles involved and that many older vehicles have a very low annual vehicle miles travelled, it is recommended that 1968 and older vehicles be excluded from an inspection program. If there is concern over emissions from these older automobiles they could be included in an inspection on resale program, especially if a safety check on resale is already required. Recent U.S. EPA calculations reveal that it may be cost-effective to exclude 1974 and older vehicles from I/M programs (50).

However, there is a "catch 22" in exempting older vehicles. The older the vehicle and the higher the mileage, the greater the likelihood of component wear or failure and therefore excess emissions. An older vehicle may emit pollutants at several times the level of a newer vehicle. An agency must survey vehicles in the proposed I/M area and analyze the possible impact of exempting older models. As noted, older vehicles could be handled as part of a transfer of ownership safety inspection.

5.3 Training and Experience

The calibre of the inspector/mechanics will be of considerable concern especially for decentralized programs where an agency's control is less direct. To ensure reasonably uniform test procedures and to protect the public, an agency's quality control program should include mechanic's training and certification.

A report on the Anchorage, Alaska I/M program highlights the need for training. Very few mechanics, approximately 6%, were able to pass the government's I/M inspection test without first taking the agency's I/M mechanic training course (62).

A Colorado government check of a number, 26, of their decentralized I/M stations revealed that "only 7 (27%) of the stations correctly identified a non-complying vehicle and made ...the repairs and/or adjustments required to bring the vehicle into compliance" (54).

The benefits of correct vehicle repair are clearly shown in the results of the investigation of the California Smog Check program (Appendix B). However, their data

also reveal that "... at least 75% of the underhood inspections... are improper". A study indicates that "...deficiencies in mechanic training and qualification tests are a contributing factor..." to limiting emissions reduction benefits (70).

Regardless of the style of I/M program i.e. centralized or decentralized, an agency will still require, on staff, a number of experienced mechanic/inspectors to certify I/M mechanics, run training programs, respond to technical questions from I/M station operators, analyze data and to liaise with the public. The agency team in Anchorage, Alaska boasts that each of their field inspectors has at least 5 years' experience in the automative repair industry (62).

5.4 Stringency - Failure Rate

When implementing an I/M program an agency must survey their in-use vehicle fleet and determine the failure rate which both they, for adequate emissions reduction, and the public, for inconvenience and cost, are willing to accept. For the Alaska I/M program an initial failure rate of 30% was "...intended to minimize the strain on available auto service industry resources and to reduce public opposition to the program..." (34). For a program employing an idle emissions test, a desired stringency level can often be set by altering the emission test failure rate cutpoints or specifications.

Following audit, several agencies discovered that the failure rates for their I/M programs were less than one half the designed failure rate. This may initially sound like a good response, but for the Colorado decentralized program they discovered a major cause of the reduced failure rate was "cheating by inspectors", i.e. passing vehicles which have actually failed the emissions inspection (53). This discovery highlights the requirement for a comprehensive quality control program (Section 3.6).

6 POTENTIAL EMISSIONS REDUCTIONS

To test potential reduction ratios, the composite HC emission factors for a fleet of vehicles involved in a fictional I/M program in an urban area in Canada were estimated. Emission factors for three different annual I/M programs were considered and compared to a 1988, NO I/M program, baseline. The programs included: I/M Only (idle emissions test only), an Anti-Tampering Program (ATP ONLY), and a program which combined the two, Table 3 (65).

As these calculations indicate, a comprehensive, well run I/M plus ATP program will result in reduced HC emissions from problem vehicles (those with emissions well in excess of set cutpoints). However, although one can calculate theoretical per vehicle or combined fleet emission factor reductions, the resultant ambient pollutant reductions for HC or ozone which may result from instituting such a program are difficult to predict.

Carbon monoxide, CO, is emitted in motor vehicle exhaust and there is a direct and roughly proportional relationship between reductions in CO from motor vehicles and improvement in ambient CO levels. "An emission reduction target that corresponds to achievement...of the CO standard...can therefore be made with reasonable certainty..." (42).

However, motor vehicles do not emit ozone in any measureable quantity. They do, however, emit NO_x and HC which are ozone or oxidant precursors, compounds which lead to or are involved in the formation of ozone. "Development of a motor vehicle...emission reduction goal for ozone is far more complex (than CO)...Ozone is...formed in the atmosphere in complex chemical reactions involving two families of directly emitted pollutants, HC and NO_x...reductions in emissions of ozone precursors do not provide proportional improvements in ozone air quality...the relationship between precursors and ozone is not even constant from area to area..." (42). There is little doubt that emission reductions of HC and NO_x will contribute to ozone reduction, the difficulty is in predicting the magnitude of the reductions which will occur as a result of an I/M program.

However, it is safe to say that an I/M program will contribute to the reduction of ambient pollution levels and that the maximum CO, HC and NO_x reductions will only occur if an I/M program is comprehensive, efficient and well run. Examples to illustrate program effectiveness with respect to emissions reductions have been taken from

TABLE 3 ESTIMATED IMPACT OF I/M ON IN-USE LDV HYDROCARBON EMISSION FACTORS

FLEET EMISSION FACTORS AS A FRACTION OF THE 1988 BASELINE								
	BASELINE		ATP ONLY		I/M ONLY		I/M + ATP	
YEAR	THC	EVAP	THC	EVAP	THC	EVAP	THC	EVAP
1988	1.00	.38	1.00	.38	1.00	.38	1.00	.38
1989	.91	.34	.86	.33	.84	.34	.80	.33
1990	.83	.30	.77	.29	.74	.30	.70	.29
1991	.75	.27	.70	.26	.66	.27	.62	.26
1992	.69	.24	.63	.23	.59	.24	.55	.23
1993	.63	.22	.57	.21	.53	.22	.49	.21
1994	.58	.20	.52	.19	.48	.20	.44	.19
1995	.54	.18	.48	.17	.44	.18	.40	.17
1996	.51	.17	.44	.16	.41	.17	.37	.16
1997	.48	.15	.41	.15	.38	.15	.34	.15
1998	.45	.15	.39	.14	.36	.15	.32	.14

NOTES:

- The emission factors were calculated using the M3C model.
- The input parameters for trips per day, miles/day, average summer temperature, etc., used in the calculations were estimates provided for the B.C. lower mainland (59).

LEGEND:

- THC = Total Hydrocarbon Emissions - Evaporative plus exhaust emissions.
- EVAP = the Evaporative hydrocarbon emissions only.
- ATP = Anti-Tampering Program.
- BASELINE = the estimated emission factor reductions which should result from the introduction of more sophisticated emission control equipped vehicles which meet the stricter 1988 model year standards.

California data, Table 4 (34, 70). These estimates appear to indicate that as far as ambient emissions reductions are concerned a poorly run I/M program, such as the Californian first generation private garage system, may be virtually useless. More recent California data credits their present decentralized I/M program with achieving higher HC and CO reductions than their previous decentralized system, but still not up to levels which theoretically could be achieved if all tampering were detected and repaired (70).

TABLE 4 ESTIMATED EFFECTIVENESS OF CALIFORNIA'S I/M PROGRAMS

I/M Program and Date	Estimated Initial Reductions of Emissions of HC	CO	NO_x
- First Generation Licenced Garage: Pre-1979*	2%	2%	1%
- Centralized: 1970 to 1984*	32%	25%	4%
- Second Generation Licenced Garage: Post-1984**	12.3%	9.8%	3.9%
- Maximum I/M Potential**	42.3%	25.7%	24.2%

* Taken from Reference 34.
** Taken from Reference 70.

Recent estimates also indicate that the decentralized I/M program implemented in Colorado in 1982 has not reached its design target of 25% reduction in CO mobile source emissions. It is predicted that the program will fall approximately 45% short of its 5 year goal. The shortfall is due primarily to deficiencies or errors introduced by individual garages (53), a conclusion similar to that reached in the California investigation.

"Laboratory studies have indicated I/M has potential to reduce hydrocarbon and carbon monoxide emissions by in excess of 25%; however, many of the I/M programs currently operating in the United States may be achieving only minimal emission reductions" (34). The authors of reference 34 continue by stating that for the theoretical benefits to be achieved the design features listed in Table 1 must be implemented as part of any I/M program.

6.1 ATP Required for NO_x and Evaporative HC Reductions

As noted earlier, another key factor when considering the potential emissions reductions from implementation of an I/M program is the necessity of an anti-tampering program (ATP). Disregarding the arguments with respect to its validity, by itself, an idle emissions test and subsequent fault repair will provide no benefit with respect to evaporative HC emission reductions and little with respect to NO_x reductions. The lack of evaporative HC emission reduction with a program which employed only an idle

emissions test is illustrated in Table 3, i.e. the evaporative emission factors are the same as the baseline values for the I/M Only case.

Although some NO_x reduction may be realized as a result of repairs to correct exhaust HC and CO emission problems (estimated to be less than 1%), an anti-tampering program (ATP), with a function test of the EGR valve plus an inspection for the presence of a catalyst, is required to realize significant NO_x reductions (66, 67, 70). Similarly an inspection of the fuel inlet cap plus the evaporative emissions cannister and related hoses is required for greater HC reduction.

Since ATP can identify defective and tampered vehicles that may pass an idle emissions test (Appendix B), an ATP will therefore help to maximize emissions reduction potential and should also reduce errors of omission.

7 DISCUSSION

An inspection and maintenance program for light duty vehicles is a method for reducing emissions in areas experiencing ambient CO and/or ozone problems related to excess motor vehicle emissions. Anti-tampering/anti-misfuelling legislation supported by an I/M program will not only discourage misfuelling and tampering but will encourage motorists to perform sufficient maintenance in order to ensure correct pollution control equipment operation and to protect their investment in this expensive hardware.

In addition to describing I/M, this report has attempted to illustrate, from published experiences with the I/M programs in the USA, not only the options available but some of the problems which may be encountered in setting up and running an I/M program. It is important to realize when discussing I/M that there are a number of factors in the USA which facilitate I/M implementation and operation in that country. None of these programs or features were available at the federal level in Canada at the time of publication of this report, Table 5.

It is important to ensure that agencies are aware of the complexity of implementing and running a comprehensive I/M program. In their initial I/M evaluation phase a Canadian province or municipality will be faced with a different situation than exists or existed in the United States. The federal Environmental Protection Agency in that country decided that where their federal CO or ozone ambient pollution standards have been exceeded due to excess vehicle emissions that an I/M program was a cost-effective method of reducing emissions. For these areas the U.S. EPA has ordered the local governments to initiate I/M by a specified date and has used a threat of withdrawal of federal funding for highway projects as an economic sanction to ensure that the local governments comply with their wishes (54). In Canada, where there are only federal ambient air objectives, not standards, the national government can only suggest I/M as one technique to reduce excess vehicle emissions.

A local government interested in I/M will therefore be required to estimate emission reductions and I/M cost-effectiveness for their area in order to justify the program. Unfortunately there is little regional airshed emission reduction or program specific cost-effectiveness data from the I/M programs in the U.S.A. to support these calculations. The U.S. cost-effectiveness data was generated for a global U.S. scenario. The lack of data on the Canadian in-use vehicle fleet will also hamper cost-effectiveness investigations.

TABLE 5 PROGRAMS OR LEGISLATION IN THE U.S.A. WHICH EASE I/M IMPLEMENTATION AND OPERATION

1. The U.S.A. has a much stronger new vehicle, government run certification program with far greater resources, especially with respect to emission control components and recalls. In Canada, the manufacturer self-certification program is backed by a spot-check style compliance program.

2. There is federal anti-tampering/anti-misfuelling legislation in the U.S.A..

3. In the U.S.A. manufacturers must provide lists of the emission control components on each engine family prior to certification. There are no such lists for Canadian specification vehicles.

4. There is federal emission control warranty legislation (5 yr, 50 000 mi) in the U.S.A. (They are also considering a longer warranty requirement.)

5. Since 1982 in the U.S.A., to restrict the impact of tampering, there has been a federal requirement for all new vehicles to meet the emissions standards over the entire range of all easily adjusted engine parameters. This has resulted in all new vehicles equipped with carburetors being fitted with carburetor seals and limited timing adjustments on many models.

6. The U.S. EPA has developed an aftermarket catalyst policy.

7. The U.S. EPA conducts yearly, random sample, in-use vehicle tampering surveys which provide data to check the success of I/M program's in specific urban areas.

8. The U.S. EPA has a federal calibration gas certification program for I/M programs.

9. The U.S. EPA has an active federal I/M audit program.

Environment Canada commissioned a study of I/M programs for Canada (54). Cost effectiveness estimates were attempted as a part of this study, but the many assumptions required to generate these data appears to compromise their validity and they have not been reproduced in this report (54).

Fortunately the original cost-effectiveness data used to justify I/M programs in the U.S.A. can be used as a rough guide (8, 50). These data were produced for older vehicle technology, i.e. pre-1981 USA model year, and as such are more applicable to the present Canadian in-use vehicle fleet than to the current in-use fleet in the U.S.A. The emissions reductions achieved for these older technology vehicles often resulted from simple carburetor adjustments and therefore repairs could often be performed for much less than the cost of repair to the more sophisticated control hardware now being installed on many new vehicles, Appendix B.

The new, more complex, technology on today's vehicles is having an impact on I/M programs in the U.S.A. The more complex control systems result in less engine parameter tampering by either vehicle owners or mechanics, but although this sophisticated equipment results in more precise engine and emission control, a change to or a malfunction of these systems particularly the catalyst and the closed-loop component electronics can result in excess emissions at much higher levels (63, 67, 70). The complexity of these new emissions control systems can also make it difficult to detect excess emitters during a simple I/M check. In California they have reported significant problems with the ability of mechanics to properly inspect and repair computer systems. "Only 30% of the mechanics appear to understand such systems" (70).

For the 1988 Canadian model year the revised vehicle emission standards will mean that virtually every new vehicle will be equipped with a 3-way catalyst, plus there will be a tendency for manufacturers to equip their latest models with costly (with respect to replacement cost) closed-loop fuel injection systems and electronic (computer) controls. Those considering I/M must recognize the changes this new technology will cause plus the controversy regarding new vehicle technology impacts on I/M programs (69, 70, 72).

Another difference between the USA and Canada which effects I/M programs is that the USA has a federal emission control component warranty requirement of 5 years or 50 000 miles. Canada does not have federal vehicle warranty legislation, but, as shown in Table 6, at the time of writing of this report, most of the major manufacturers with vehicles on the market in Canada offer a voluntary warranty similar to those required by law in the USA.

TABLE 6 EMISSION CONTROL WARRANTIES BY MANUFACTURER IN CANADA*

American Motors****	-	5	years/80 000 km***
Audi	-	5	years/80 000 km
BMW	-	5	years/80 000 km
Chrysler	-	5	years/80 000 km
Dacia	-	12	months/20 000 km**
Ford	-	5	years/80 000 km
General Motors	-	5	years/80 000 km
Honda	-	5	years/80 000 km
Hyundai	-	5	years/80 000 km
Innocenti	-	5	years/80 000 km
Jaguar	-	5	years/80 000 km
Lada	-	12	months/20 000 km
Mazda	-	5	years/80 000 km
Mercedes Benz	-	5	years/80 000 km
Nissan	-	5	years/80 000 km
Porsche	-	5	years/80 000 km
Rolls Royce	-	5	years/80 000 km
Saab	-	5	years/80 000 km
Skoda (Skocar Inc.)	-	12	months/20 000 km
Subaru	-	12	months/unlimited
Suzuki	-	5	years/80 000 km
Toyota	-	5	years/80 000 km
Volvo	-	5	years/80 000 km
Volkswagen	-	5	years/80 000 km

* Prepared by Transport Canada, November, 1986. Subject to revision at any time without notice.

** Catalyst supplier covers catalytic converter 5 years/80 000 km.

*** Commencing model year 1987, the warranty is 12 months/20 000 km for previous model years.

**** In 1987 the company name changed to Jeep-Eagle.

As noted earlier, the identification of the emission control components originally installed on vehicles sold in Canada will also cause difficulties for prospective I/M administrators. Unlike the USA, there is no requirement in Canada for manufacturers to supply this information to the federal government. For older vehicles, agencies will have to develop techniques to identify the emission control equipment on vehicles in their area. Newer vehicles will cause fewer problems. Beginning with the 1988 model year, all but a few of the new vehicles sold in Canada will have equipment identical to that installed on similar vehicles in the USA, and, therefore, as of the 1988 model year, the EPA equipment lists will apply to vehicles sold in this country.

Because of the many uncertainties involved in the implementation of an I/M program, it may be wisest to introduce such a program in stages. A staged or phased approach allows an agency time to better tailor a program to their area or to reconsider the need for compulsory inspections. Activities which could be employed to support anti-tampering/anti-misfuelling legislation and to phase-in an I/M program include: an extensive public relations campaign; legislation to ensure that vehicles which are resold have not suffered tampering; an education program for vehicle owners and mechanics; an inspection on resale requirement; plus a series of random vehicle "spot checks" to initiate the public to inspection requirements and to gather data for evaluating the effectiveness of certain I/M program parameters.

8 CONCLUSIONS

Motor vehicle inspection and maintenance programs which include an anti-tampering program should be considered for certain urban areas as a method of reducing excess light duty vehicle emissions which result from tampering, misfuelling and insufficient maintenance.

Manufacturers have designed vehicles which comply with the federal government emission standards and these vehicles, if maintained and not abused, should continue to meet these emission standards for their useful life (5 years or 50 000 miles, by definition) and possibly even longer. An I/M program will help to ensure that the emission control systems originally installed on a vehicle are in place and that the vehicle's emissions are kept at a low level throughout its useful life. An I/M program will also ensure that vehicle owners receive the benefits they deserve from the sophisticated emission control systems for which they have paid a considerable amount of money and should encourage owners to maintain their vehicle's emissions control systems.

Agencies considering an I/M program for their area are advised to make use of the considerable quantity of information accumulated from the operation of I/M programs in the USA. A bibliography of I/M related reports and documents has been appended to this report, Appendix C.

APPENDIX A

MOTOR VEHICLE EMISSION STANDARDS PLUS THE FEDERAL TEST PROCEDURE

APPENDIX A

A.1.0 Vehicle Emission Standards

The exhaust emissions standards for pre-1988 model year, new, light duty vehicles, presented in Table A-1, reproduced from the "Consolidation of the Motor Vehicle Safety Act and Regulations", Transport Canada document TP4360E, dated 1 April, 1983, were promulgated in 1975. For 1988 model year vehicles a set of stricter emission standards were enacted; these revised standards are virtually equivalent to the standards which have been in effect in the U.S.A. since 1981.

For pre-1988 model years, a light duty vehicle (LDV) was defined as a passenger car or any other vehicle having a gross vehicle weight rating, GVWR, of 6000 lbs. (2721.6 kg) or less. For the 1988 model year and on, a light duty vehicle has been redefined as any motor vehicle designed primarily for the transportation of persons having a designated seating capacity of not more than 12 persons and a light duty truck as any motor vehicle rated at 3855.6 kg (approximately 8500 lbs.) GVWR or less.

A.2.0 The Federal Test Procedure - FTP

When a new motor vehicle is tested for compliance with the standards shown in Table A-1 its emissions are measured by following the Federal Test Procedure (FTP) as detailed in the Motor Vehicle Safety Act. The exact procedure is too lengthy to reproduce in this report, but it is ably illustrated in Figure A-1. The vehicles are driven (on a dynamometer) over the cycle as shown in Figure A-2.

TABLE A-1 MOTOR VEHICLE EMISSION STANDARDS FOR NEW LIGHT DUTY VEHICLES

	Canada 1975 to 1987 Model Years				Canada for 1988 Model Year and on***				
Emission Standards	CO	HC	NO_x	Part.	CO	HC	NO_x		Part.
AUTOMOBILES									
g/km	15.54	1.24	1.93	NS	2.11	0.25	0.62		0.12
g/mi	25.0	2.0	3.1	NS	3.4	0.41	1.0		0.20
Evap.-g/test		2.0(C)				2.0(S)			
TRUCKS									
0 - 6000 lbs. GVWR					0 to 8500 lbs (3855.6 kg) GVWR				
g/km	15.54	1.24	1.93	NS	6.21	0.50	0.75*	1.06**	0.16
g/mi	25.0	2.0	3.1	NS	10.0	0.8	1.2*	1.7**	0.26
Evap.-g/test		2.0(C)				2.0(S)			
6000 - 8500 lbs. GVWR		($HC + NO_x$)							
g/km	-	-	-	-					
g/mi	-	-	-	-					
g/bhp-hr	40.0	16.0		NS					
Evap.-g/test		NS							

Part.: diesel particulates
Evap.: evaporative HC emissions
GVWR: gross vehicle weight rating
NS: no standard in effect
(C): cannister test
(S): SHED test

Note: At present, in Canada, vehicles with a GVWR of greater than 6000 lbs are considered Heavy Duty Vehicles. In the revised standards, which come into effect for the 1988 model year, all vehicles of 3855.6 Kg (8500 lbs.) or less are classed as Light Duty Vehicles. However, for NO_x emissions there will be 2 categories based on loaded vehicle weight: * 0 - 1701.0 kg loaded vehicle weight.
** over 1701.0 kg loaded vehicle weight.

*** Since 1981, the U.S.A. (49 state) standards for automobiles have been virtually the same as the Canada 1988 standards.

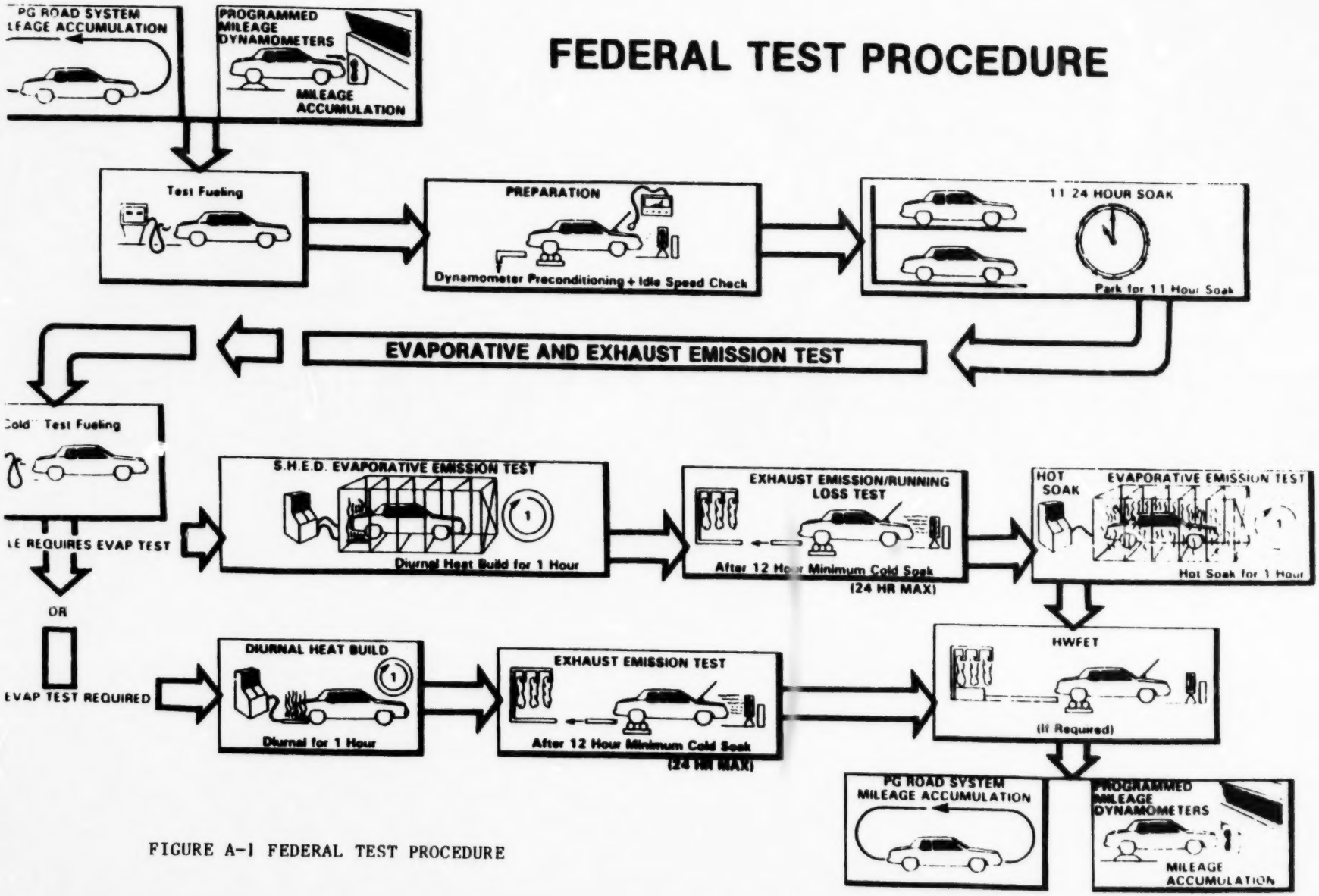
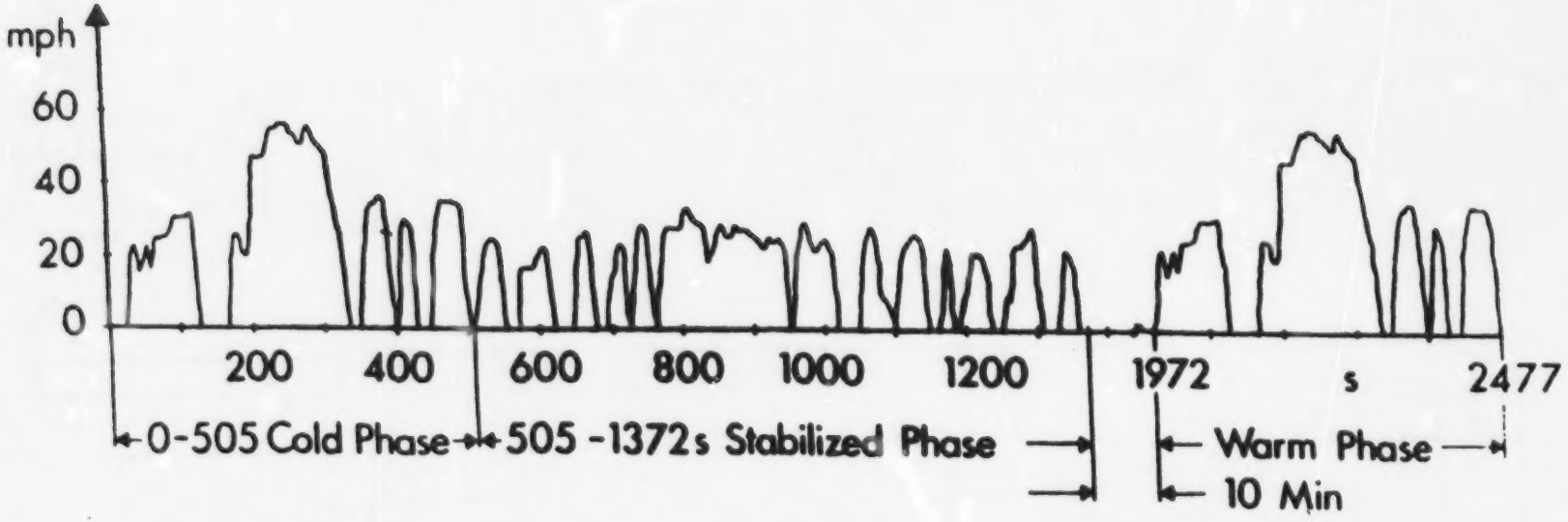


FIGURE A-1 FEDERAL TEST PROCEDURE



City (Exhaust test) Cycle

FIGURE A-2 FTP DRIVING CYCLE

APPENDIX B

RECENT CALIFORNIA I/M PROGRAM DATA

APPENDIX B

The following tables reveal some interesting trends with respect to the decentralized I/M program which has operated in California since March, 1984 (70).

Table B-1 indicates the differences in failure rates achieved if idle emissions test (tailpipe) results are compared to anti-tampering inspection (underhood) results. Note that the anti-tampering inspection is particularly effective for 1975 to 1979 model year vehicles and both are considerably less effective identifying emissions problems with new technology (California specification 1979 model year and newer) vehicles.

Tables B-2 and B-3 show the differences in emissions before and after I/M repairs while Table B-4 shows the theoretical emissions benefits from improving the existing I/M program run by the California Air Resources Board.

Table B-5 illustrates the effect of model year and repair cost waivers on I/M repairs.

TABLE B-1 CARB INSPECTION RESULTS FOR THE 1986 ROADSIDE SURVEY (70)

Model Year - California Emission Specifications	Failure Rate		
	Tailpipe	Underhood	Overall
Pre-1975 Models	38.9%	70.3%	81.5%
1975-1979 Models	35.6%	62.1%	74.4%
Post-1979 Models	13.9%	14.6%	24.7%
All Model Years	25.3%	39.5%	50.4%

TABLE B-2 EMISSIONS BEFORE AND IMMEDIATELY AFTER REPAIR FOR VEHICLES THAT FAIL THE CARB SMOG CHECK (70)
(All emissions in grams/mile, based on FTP)

Pollutant	Test Condition	Model Year Group*			
		Pre-'75s	1975-1979	Post-'79	All Vehicles
HC	Before I/M	10.49	4.25	1.89	5.24
	After repair	6.59	3.16	1.29	3.52
	Reduction	37.2%	25.5%	31.4%	32.9%
CO	Before I/M	70.73	49.27	32.04	49.73
	After repair	63.56	39.33	21.13	40.21
	Reduction	10.1%	20.2%	34.1%	19.2%
NO_x	Before I/M	3.31	2.75	1.26	2.43
	After repair	3.02	2.48	1.21	2.22
	Reduction	8.8%	9.9%	3.9%	8.5%

* Model Year - California Emission Specifications

TABLE B-3 CARB-CHANGE IN FLEET EMISSIONS DUE TO SMOG CHECK (70) (grams/mile)

	HC	CO	NO_x
Before I/M	2.11	23.71	1.55
After I/M	1.85	21.39	1.49
Percent Reduction	12.3%	9.8%	3.9%

TABLE B-4 THEORETICAL BENEFITS OF IMPROVING THE CARB SMOG CHECK PROGRAM (70)

	HC	CO	NO_x
Baseline Benefits	12.3%	9.8%	3.9%
Eliminate All Tampering	+16.6%	+10.7%	+10.9%
Repair Non-Tampering Exhaust Emission Defects	+6.4%	+5.2%	+9.4%
Fix PCV Defects	+7.0%	-	-
	42.3%	25.7%	24.2%

TABLE B-5 EFFECT OF REPAIR COST CEILING ON FAILED VEHICLES WITH OBVIOUS DEFECTS

Model Years - California Emission Specifications	Pre-'75 Models	'75-'79 Models	1980 and Later Model	sOverall
Repaired @ Smog Check	69%	64%	46%	59%
Should Have Been Repaired Under $50 Cost Ceiling	20%	16%	20%	19%
Additional Repairs Possible w/ $150-200 Cost Ceiling	11%	16%	18%	15%
Additional Repairs Possible w/ $400-500 Cost Ceiling	0%	4%	16%	7%
Totals	100%	100%	100%	100%

APPENDIX C

MOTOR VEHICLE INSPECTION AND MAINTENANCE PROGRAM BIBLIOGRAPHY

APPENDIX C

C.1 BIBLIOGRAPHY - PREPARED BY D. COPE, REVISED AUGUST, 1987

1. "Abstracts of I/M Technology Reports and Policy", U.S. EPA, November, 1984.

2. "Inspection/Maintenance Program Implementation Summary", U.S. EPA, July, 1986.

3. "Anti-Tampering and Anti-Misfuelling Programs to Reduce In-Use Emissions from Motor Vehicles", EPA-AA-TSS-83-10, 31 December, 1983.

4. "Compilation of Inspection/Maintenance Facts and Figures", Armstrong, J., et al., EPA-AA-IMS/81-15, June, 1981.

5. "Decentralized Private Garage I/M Program Cost Calculation Worksheet", EPA-IMS-006/CW-2, August, 1979.

6. "Low-Cost Approaches to Vehicle Emissions Inspection and Maintenance", EPA-AA-IMS/81-7, October, 1981.

7. "Centralized I/M Program Cost Calculation Worksheet", EPA, IMS-005/CW-1, August, 1979.

8. "Update on the Cost-Effectiveness of Inspection and Maintenance", Darlington, T., EPA-AA-IMS-81-9, April, 1981.

9. "The Case for Auto I&M", Walsh, M.P., The Environmental Forum, August, 1982, plus "Car Lines", Vol. 2, Number 9, November, 1986.

10. "Use of Lead Sensitive Test Papers for Vehicle Inspections", McKee, H., Journal of the Air Pollution Control Association, July, 1985.

11. "New York Metropolitan Area Implementation Plan", Davis, E.W., NYS Department of Environmental Conservation, 1984.

12. "Motor Vehicle Emission Control Tampering and the Role of Replacement Catalysts for In-Use Emission Factors", Bertelsen, B.I., Manufacturers of Emission Controls Assoc., 1984.

13. "Vehicle Inspection and Maintenance - What's Next?", Wallis, R.R., Texas Air Control Board, 1984.

14. "Overview of I/M Activities and Issues", Cabaniss, J.M., EPA-AA-IMC-84-1, 1984.

15. "Summary of Aftermarket Catalyst Workshops", Albrink, S.T., U.S. EPA, 1 March, 1985.

16. "Motor Vehicle Emissions Inspections-Ohio", Telex, 7 January, 1985.

17. "EPA Audits of State and Local Inspection/Maintenance Programs", Lorang, P.A., et al., U.S. EPA, 85-40.4, June, 1985.

18. "Inspection and Maintenance from the Manufacturer's Point of View", U.S. Motor Vehicles Manufacturers Association, Millerick, D., 1984.

19. "Misfuelling Emissions of Three-Way Catalyst Vehicles", Michael, R.B., U.S. EPA, SAE Paper 841354, October, 1984.

20. "I/M Short Tests and Cutpoints for 1981 and Newer Emission Control Technology", Duleep, K.G., et al., Energy and Environmental Analysis Inc., SAE Paper 851185, May, 1985.

21. "Auto Test 85" Centre of Energy Studies, Halifax, 30 August 1985, (Halifax Test Clinic Results).

22. "Evaluation of Applicability of the INCOLL Procedure as an I/M Strategy", Smuda, B., EPA-AA-IMS/81-5, November, 1980.

23. "Costs and Benefits of Reducing Lead in Gasoline, Final Regulatory Impact Analysis", EPA-230-05-85-006, February, 1985.

24. "Motor Vehicle Tampering Survey-1983", U.S. EPA, August, 1984.

25. "Motor Vehicle Tampering Survey-1984", U.S. EPA, September, 1985.

26. "Automotive Emission Systems Applications Guide, 1966-1984", Colorado State University, 1984.

27. "Quality Assurance in Decentralized I/M Networks: Analyzer Measurement Error and Field Performance", Pienta, W., et al., Auto Emissions, Lab., New York State, SAE Paper 852110, October, 1985.

28. "Visual Inspections in the Oregon I/M Program", Jasper, W., et al., Oregon DOEQ, SAE Paper 852109, October, 1985.

29. "An Evaluation of a Colorado Short Vehicle Emission Test (CDH-226) in Predicting Federal Test Procedure (FTP) Failures", Ragazzi, R., et al., Colorado Health Department, SAE Paper 852111, October, 1985.

30. "Design Considerations for Aftermarket Converter", Fiero, W., et al., Davison Chemical of W.R. Grace & Co., SAE Paper 852121, October, 1985.

31. "Design Considerations for an Aftermarket Catalytic Converter Product Line", Shaff, G., Echlin Inc., SAE Paper 852122, October, 1985.

32. "Gasoline Vapour Pressure Reduction an Option for Cleaner Air", Stebar, R., et al., Environmental Activities, G.M. Corp., SAE Paper 852132, October, 1985.

33. "A Report with Recommendations for the Reduction of Emissions from In-Use Light Duty Motor Vehicles", Gourley, D., Cope, D., Solman, R., Shantora, V., Environment Canada, Manuscript Report, IP-34, May, 1985.

34. "Design and Enforcement of I/M Programs for Maximum Effectiveness", Austin, T., et al., Sierra Research Inc., SAE Paper 852108, October, 1985.

35. "1986 Fuel Consumption Guide", Transport Canada, October, 1985.

36. "When Somethings Missing, Guide to the Video on Pollution Control Devices", Environnement Québec, Environment Canada, En 40-340/1986E, September, 1986.

37. "Vehicle Inspection and Maintenance, What's Next?", Wallis, R.R., Darcy, D.L., Klausmeier, B., APCA Conference, Kansas City, 15 February, 1984.

38. "Opinions and Practices of Canadian Mechanics Recording Vehicular Pollution Control", Optima Applied Social Research Inc. for Environment Canada, IP-58, April, 1986.

39. "Automobile Misfuelling Study Results of a National Public Opinion Survey", Optima Applied Social Research Inc. for Environment Canada, IP-56, April, 1986.

40. "Analysis of Emission Test Failure Rates in Centralized I/M Programs", for U.S. EPA by Energy and Environmental Analysis Inc., 68-03-1865, September, 1986 DRAFT.

41. "Motor Vehicle Emission Inspection/Maintenance Information Kit", EPA-460/3-78-013, 1978.

42. "California's Reasonable Extra Efforts Program for Motor Vehicles", California Air Resources Board, June, 1986.

43. "A Study of the Effectiveness of Mechanic Training for Vehicle Emissions Inspections and Maintenance Programs", Michael, R.B., EPA-AA-IMS-81-11, April, 1981.

44. "Harris County (Texas) Vehicle Parameter Inspection and Maintenance Program Description", January, 1984.

45. "Making Emission Control System Warranties More Effective", Appleby, M.R., Jones, A.D., Automobile Club of Southern California, February, 1984.

46. "Emissions Reductions from Inspection and Maintenance: Vancouver (Washington) Versus Portland Snapshot", Michael, R.B., EPA-AA-IMS-81-18, August, 1981.

47. "The Present and Future Air Quality Benefits of Inspection and Maintenance Programs for In-Use Motor Vehicles", Johnson, T.W., Hamilton Test Systems Inc., 4 October, 1983.

48. "Patterns of Vehicle Misfuelling in 1981 and 1982: Where, When, What Vehicles, and How Often?", McNutt, B.D., Elliot, D., and Dulla, R., SAE 841345, 1984.

49. "I/M Status", Draft Report, U.S. EPA, 8 September, 1986.

50. "Recent EPA Modeling of the Costs and Emission Reduction of Enhanced I/M Programs", Draft Report, U.S. Report, U.S. EPA, September, 1986.

51. "Inspection and Maintenance for Heavy-Duty Diesel Vehicles - Part 1 - Evaluating the Need", Weaver, C.S., Klausmeier, R.F., SAE Paper 861546, October, 1986.

52. "A Discussion of Reported Maintenance and Repair Expenses in an I/M Program", Jasper, P.E., SAE Paper 861547, October, 1986.

53. "A Sample of I/M Program Evaluation Methods and Procedures as Applied to Colorado's Vehicle Inspection Program", Gallagher, J., et al., SAE Paper 861548, October, 1986.

54. "An Overview and Analysis of Emissions-Related Inspection and Maintenance (I/M) Programs for In-Use Motor Vehicles", Sypher: Mueller International Inc., for Environment Canada, May, 1987.

55. "A Preliminary Assessment of Various Short Tests in Identifying Excess Vehicle Emissions", Ragazzi, R., et al., Colorado Department of Health, APCA paper 85-40.2, June, 1985.

56. "Tampering and Misfuelling - An Air Quality Perspective", Mannato, A.S. and Hoover, S.E., U.S. EPA, APCA Paper 85-40.3, June, 1985.

57. "Real World Approaches to Inspection and Maintenance Quality Assurance: Field Auditing Issues", Carhart, B.S., Engineering Science Inc., APCA Paper 85-40.5, June, 1985.

58. "Sale and Use of Aftermarket Catalytic Converters", U.S. EPA Notice of Proposed Enforcement Policy, Federal Register, Vol. 51, No. 150, 28114 to 28119, 5 August, 1986.

59. "Description of the Mobile3C Vehicle Emissions Factor Model", Cope, D., Libman, J., Environment Canada, Draft, December, 1986.

60. "Motor Vehicle Tampering Survey - 1985", U.S. EPA, November, 1986.

61. "Motor Vehicle Tampering Study", Survey Data Research, Inc., for the Motor Vehicle Manufacturers Assoc. of the United States, July, 1985.

62. "Vehicle Inspection and Maintenance - First Annual Report", Municipality of Anchorage, October, 1986.

63. "Inspection and Maintenance of New Technology Vehicles in Maryland", Landman, L., U.S. EPA-AA-TSS-I/M-86-06, September, 1986.

64. "Vehicle Inspection and Maintenance Program Awareness Survey", Dittman Research Corp., for Municipality, of Anchorage, November, 1985.

65. "Assessment of Light Duty Gasoline Vehicles Emissions Inspection and Maintenance Program Options for the Lower Mainland Area", Task Force Report to the Lower Mainland Oxidant Committee, B.C. MOE, April, 1987.

66. "An Overview of Vehicle Emissions Control System Tampering", Cope, D., Transportation Systems Division, Environment Canada, Draft, April, 1987.

67. "The Effect of Control Component Removal or Malfunction on Vehicle Emissions", Ostrouchov, N., Environment Canada Manuscript Report, March 1987.

68. Notice No. 87-18, California Air Resources Board, 13 May, 1987.

69. "I/M Effectiveness with Today's Closed Loop Systems", Haskew, H.M., et al., General Motors Corporation, SAE Paper 871103, May, 1987.

70. "Evaluation of the California Smog Check Program", Sommerville, R.J., Cackette, T., Austin, T.C., SAE Paper 870624, February, 1987.

71. "Understanding Automobile Emissions", Environment Canada and the Petroleum Association for Conservation of the Canadian Environment, P.A.C.E., October, 1986.

72. "Inspection"Maintenance in the 1990's", Armstrong, J., et al., U.S. Environmental Protection Agency, SAE PAPER 870621, February, 1987.

73. "Results of Plumbtesmo Tailpipe Testing", U.S. Environmental Protection Agency, EPA-AA-TSS-86-07, September, 1986.